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Review

Burn regime matters: A review of the effects of prescribed fire on vertebrates in the longleaf pine ecosystem

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A clear understanding of how management influences vertebrate biodiversity is critical for the conservation of rare ecosystems, such as the longleaf pine (*Pinus palustris*) ecosystem in the southeastern United States. We used scientific literature to assess how vertebrate use of the longleaf pine ecosystem (High or low) differed in response to high (1–3 years), moderate (>3–5 years), and low (>5 years) burn frequencies. For all species combined, we found that the number of high use (HU) species associated with moderately burned forests (n = 140) was 22% and 33% greater than in high (n = 115) and low burn (n = 105) frequency forests, respectively. This pattern was most clear for Aves and Reptilia. Specifically, the number of HU species associated with moderate burn frequencies (Aves – n = 69; Reptilia – n = 36) was 21% and 25% greater for Aves and 56 and 63% greater for Reptilia than high (Aves – n = 57; Reptilia – n = 23) and low burn frequencies (Aves – n = 55; Reptilia – n = 22), respectively. We found no difference in the number of HU species across burn frequencies for Amphibia or Mammalia. For species considered longleaf pine specialists, across all vertebrate taxa the number of HU species was associated with areas of high and moderate burn frequencies. We posit that moderate burn frequencies had the greatest number of HU species because of requirements for multiple habitat types, structural diversity, and habitat components that are reduced in, or not provided by, areas with high burn frequencies. If conservation of specific longleaf pine specialists that rely on habitat created by high fire frequencies (e.g. Red-cockaded woodpeckers) is the objective, we suggest managing with high burn frequencies at the local scale. Conversely, if management objectives include maximizing wildlife diversity, managers should use a more variable fire regime across the landscape, from annual to less frequent 5 year burn intervals, to maintain localized patches of oaks and increase the compositional and structural diversity within the system.

Contents

1. Introduction . . . 215
2. Methods . . . 215
   2.1. Data collection . . . 215
   2.2. Fire frequency . . . 216
   2.3. Measuring use . . . 216
   2.4. Data analyses . . . 216
3. Results . . . 217
4. Discussion . . . 218
   Acknowledgements . . . 219
   Appendix A. Supplementary material . . . 219
   References . . . 219

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1. Introduction

Across the globe, dominant ecosystems (e.g. estuarine and coastal [worldwide]; coastal sage scrub [California]; longleaf pine [southeastern United States]; Lotze et al., 2006; Noss et al., 1995) have declined in size and functionality due to anthropogenic impacts (Ellis et al., 2010; Hannah et al., 1994; Vitousek et al., 1997). One ecosystem that has been the subject of numerous conservation efforts is the longleaf pine (*Pinus palustris*; LLP) ecosystem. The LLP ecosystem has been described as bilayered with a diverse understory dominated by wiregrass (*Aristida beyrichiana* and *A. stricta*) or bluestem (*Schizachyrium* spp.), a sparse midstory of pyrophytic oaks, described in detail by Hiers et al. (2014), and a canopy of LLPs (Jose et al., 2006). The LLP ecosystem historically covered approximately 37,000,000 ha in the southeastern United States, but less than 3% remains (Frost, 1993). The ecosystem declined due to large-scale clearcutting of old-growth LLP forests prior to the 1930s, and the encroachment of mesic hardwoods and woody understory vegetation associated with fire suppression (Frost, 1993).

Similar to other imperiled ecosystems, management success within the LLP ecosystem has been determined by comparing metrics (e.g. plant and wildlife species richness) of the restored site to reference sites (e.g. Litt et al., 2001; Provencher et al., 2001; Steen et al., 2013a,b). Reference sites are often selected using accounts from travelers during the 1700–1800 s that describe an open, bilayered landscape with few oaks (e.g.; Brockway et al., 1998; Harper et al., 1997; Means, 1996; Myers, 1990). To mimic reference conditions, prescribed fire on 1–3 year burn intervals and herbicide and manual oak removal have been commonly used for restoration (Lewis and Harshbarger, 1976; Provencher et al., 2001). Yet, historical descriptions may be biased because travelers would have used the path of least resistance, leading to descriptions of uncharacteristically open landscapes (Landers et al., 2001). Additionally, fire likely would not have been spatially or temporally constant as the recommended 1–3 year burn interval suggests. Dendrochronology data indicate that average fire return intervals within longleaf pine ecosystems may have been from 2.2 to 6.7 years (Henderson, 2006; Huffman et al., 2004; Stambaugh et al., 2011), and ranging from 0.5 to 12 years (Stambaugh et al., 2011) prior to the implementation of fire suppression by settlers in the 1930s. These variable fire frequencies would have provided variation in vegetative structure and environmental conditions, including areas similar to LLP reference sites, and areas containing more hardwoods and increased structural diversity.

Maintenance of biodiversity, including vertebrate diversity, is recognized as a central restoration objective (SER, 2004) because biodiversity loss has been linked to reduced ecosystem function and the alteration or elimination of ecosystem services (Cardinale et al., 2012). Nevertheless, few management plans specifically embrace biodiversity as a metric for evaluating success and instead focus on the needs of a few rare species (e.g. umbrella, flagship, and keystone species; Simberloff, 1998) and their responses to management (Landres et al., 1988). Practical and ecological limitations including limited budgets, the difficulty of determining the abundances and habitat requirements of a variety of species within an area, variability in spatial and temporal responses, and the possibility that management for one species may negatively influence another cause this discrepancy (Margules and Pressey, 2000). Although managing for surrogate species is done under the auspices of maximizing biodiversity, there is little research supporting these assumptions (Andelman and Fagan, 2000; Simberloff, 1998) and the use of surrogates to manage biodiversity is context dependent (Bichet et al., 2016; Jones et al., 2016; Nicholson et al., 2013; White et al., 2013).

LLP management goals often focus on single species that are rare and/or provide recreational opportunities (e.g. Red-cockaded woodpeckers and bobwhite quail, respectively). Yet, without quantification it is impossible to determine if management efforts guided by the requirements of surrogate species within an ecosystem actually benefit biodiversity, or if they have unintended consequences. Additionally, there is increasing recognition that management should focus on whole ecosystems rather than single, rare or imperiled species (Hallett et al., 2013; Jackson and Hobbs, 2009; Perring et al., 2015; Suding et al., 2015). Although rare species are, and should, be a conservation priority, the role of common species in shaping and increasing the resistance and resiliency of ecosystems cannot be ignored within the context of rapid global change and uncertainty (Gaston, 2011; Gaston and Fuller, 2008; Golladay et al., 2016; Jackson and Hobbs, 2009; Lindenmayer and Likens, 2011). Common species are often not considered within management goals because it is assumed that common species will remain common and they are typically considered less valuable, which is evidenced by the use of the words "weedy" and "trash" to describe them (Gaston, 2011). Yet, many common or once common species are in decline (e.g. Rusty blackbirds [*Euphagus carolinus*; Greenberg and Droege, 1999], spotted skunks [*Spirogale putorius*; Gompper and Hackett, 2005], several bird species in Europe [Inger et al., 2015; Krebs et al., 1999], regal fritillary butterflies [*Speyeria idalia*; Powell et al., 2007], several species of bumblebees [Cameron et al., 2011]) and some have gone extinct (e.g. Carolina parakeet [*Conoropsis carolinensis*] and passenger pigeon [*Ectopistes migratorius*; Gaston and Fuller, 2008]). Management that deemphasizes common species ignores the important roles that common species play (e.g. propagule dispersal, pollination, trophic interactions [Dickman and Steeves, 2004; Gaston, 2010; Goldingay et al., 1991; Gregory et al., 2005]) in shaping the environment that less common species rely on (Gaston, 2011).

It is clear that current LLP management promotes understory plant diversity similar to reference sites (Brockway et al., 1998, 2005; Brockway and Outcalt, 2000) and longleaf pine specialists, but the influence of these practices on vertebrate diversity are less clear. There have been numerous studies on the response of specific wildlife species to LLP restoration (e.g. Litt et al., 2001; Stratman and Pelton, 2007; Armitage and Ober, 2012). Still, there is no unified understanding of how LLP management may influence vertebrate diversity though prescribed fire influences vegetative structure and subsequently the food resources which wildlife rely on (e.g. soft mast; Hiers et al., 2014; Lashley et al., 2014). Consequently, the objective of our review was to determine if frequent prescribed fire (1–3 years) equates to a greater diversity of wildlife within the LLP ecosystem. Specifically, the goals of our research were to determine (1) if restoration to reference conditions utilizing frequent fire in LLP increases vertebrate diversity, (2) what fire return interval promotes the greatest vertebrate diversity, and (3) if restoration to reference conditions with frequent fire enhances the prevalence of specialized species.

2. Methods

2.1. Data collection

There are approximately 733 terrestrial vertebrates within the coastal plain of the southeastern United States (Griep and Collins, 2013), but many are not associated with, or rarely inhabit, the LLP ecosystem. We used a cumulative species list of four classes of vertebrates (Aves, Mammalia, Amphibia, and Reptilia) found within the LLP ecosystem (Means, 2006; Appendix Table A) to delineate vertebrate LLP inhabitants from other species inhabiting the southeastern U.S., and to determine which species were